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Vogler

DWARF MISTLETOE-RELATED MORTALITY OF PONDEROSA AND JEFFREY PINES AT FIVE CAMPGROUNDS IN CALIFORNIA AND NEVADA

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ABSTRACT

Western dwarf mistletoe (Arceuthobium campylopodum) can be a serious parasite of pines in campgrounds as well as in timber-producing forests. To measure dwarf mistletoe-related mortality of ponderosa and Jeffrey pines, we collected infection intensity and tree vigor data at five forested campgrounds in southern and northeastern California and on the Nevada shore of Lake Tahoe. Annual mortality over eight years was compared to mistletoe infection class, radial growth, and age at death. Overall, 7% (206) of the pines died of natural causes on all five plots. The proportion of trees killed increased with the severity of infection: by the end of the survey, 3% of the uninfected, 4% of the slightly-infected, 7% of the moderately-infected, and 22% of the severely-infected pines had died. Cambium-feeding insects, including bark beetles, pine engravers, and flatheaded borers, were involved in the deaths of all but one of the pines. More than 80% of the trees that died were slow-growing (10-year radial growth 10 mm [0.4 in] or less) and younger than 100 years of age. We discuss the differences in dwarf mistletoe intensity, stand vigor, and pattern of mortality at each of the campgrounds, and consider the implications of these results for campground management.

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INTRODUCTION

Dwarf mistletoes (Arceuthobium spp.) are serious parasites of pines in timber-producing forests. They reduce growth and yield, and often predispose their hosts to insect attack and premature death. Although frequently ignored by visitors and campground managers, dwarf mistletoes also threaten pines in campgrounds and other recreation sites. Because campgrounds are designed for people, campground trees are valued to the extent that they enhance or detract from the visitor's experience. Their recreational, not their timber, values determine how managers will judge the effects of parasites like dwarf mistletoe.

The chronic growth losses and deformations that dwarf mistletoes cause are unimportant in campgrounds as long as the trees continue to live and provide shade and beauty. Large mistletoe brooms can be hazards within campsites, but they may also contribute to screening between camps. The dwarf mistletoe plants themselves, though unsightly to some, are often ignored; when recognized, they can become an interesting addition to a visitor information program. Dwarf mistletoe infestation becomes a major concern, however, when many trees are killed prematurely and campgrounds are gradually denuded, especially where natural regeneration is sparse and planting survival poor.

To better understand the magnitude and importance of dwarf mistletoe-related mortality, we began an evaluation of several mistletoe-infested campgrounds in California and Nevada in 1973. We collected baseline data on the campground pines in 1973 and 1974, and followed the annual tree mortality through 1981. The results illustrate what the campground manager may expect if he fails to treat dwarf mistletoe infestations in pine stands.

METHODS

Our purpose was to examine the relationship between western dwarf mistletoe (A. campylopodum) and the premature deaths of ponderosa and Jeffrey pines in selected campgrounds. Since we expected average annual mortality to be 2% or less, we needed large, long-term plots where each dead tree could be recorded quickly and reliably at little cost.

CAMPGROUND SELECTION

We sought potential survey sites that were,

- developed, high-use campgrounds with almost pure ponderosa or Jeffrey pine in both overstory and understory;
- pine stands with a high incidence of dwarf mistletoe infestation, ranging in intensity from slight to severe;
- managed so that the dead and dying pines were removed yearly, preferably once in the spring or fall;

- unaffected by past dwarf mistletoe suppression, so that the parasite had spread and intensified with little or no interference;

- free of substantial infection by other pathogens, including Elytroderma disease (caused by Elytroderma deformans), annosus root disease (caused by Heterobasidion annosum), and air pollution.

Because we suspected a relationship between insect activity and dwarf mistletoe severity, we included in the survey campgrounds with a history of attacks by cambium-feeding insects, including bark beetles (Dendroctonus spp.), the California flatheaded borer (Melanophila californica), and pine engravers (Ips spp.).

In 1973 and 1974 we examined 25 campgrounds on the Modoc, Lassen, Plumas, Sierra, and Cleveland National Forests and at the Lake Tahoe Basin Management Unit. Most sites were unsuitable because of low dwarf mistletoe intensity, a history of mistletoe control, the confounding influence of other pests, too few host pines in mixed stands, poor stocking, or severe disturbance from campground construction and maintenance.

We found five campgrounds suitable for survey plots: Merrill, Cave, and Bridge on the Lassen National Forest in northeastern California; Nevada Beach at Lake Tahoe in the central Sierra Nevada; and Laguna on the Cleveland National Forest in southern California (Figure 1). The campgrounds were all in stands typical of, or similar to, the dry, eastside Sierra pine type (Hallin 1959), but they were not strictly comparable in site, stocking, or mistletoe intensity. Nevertheless, they represent a range of dwarf mistletoe infestations that may be found in campgrounds where the parasite has not been suppressed.

CAMPGROUND DESCRIPTIONS

The stand characteristics and histories of the individual campgrounds are as follow. Included in the descriptions are measures of stocking (basal area) and of site productivity (site index [Meyer 1938] expressed as the height of dominant or codominant pines at 100 years of age).

- MERRILL: All-aged ponderosa and Jeffrey pine stand, with a few overstory and 20-30% understory white fir. The campground was built beside the southwest shore of Eagle Lake in 1965. Heterobasidion annosum was prevalent in nearby pine and fir stands.

  Basal area = 20-100 m^2/ha (85-435 ft^2/a)
  Site $Index_{100}$ = 26-34 m (85-110 ft).

- CAVE: All-aged ponderosa pine stand near Hat Creek, with a few scattered Jeffrey pines and western junipers. The roads and campsites were built around 1960. Elytroderma disease

was present in the campground, but only one pine was infected within the plot; H. annosum was found nearby.

Basal area = 30-65 m^2/ha (130-285 ft^2/a)
Site Index$_{100}$ = 27-30 m (90-100 ft).

- BRIDGE: Stand of pole-size and larger ponderosa pine beside Hat Creek, with 10-20% incense-cedar and a few sugar pine and white fir. Although the roads and campsites were constructed in 1970-71, the site has been used for camping for at least 40 years. H. annosum was present in the vicinity.

Basal area = 35-45 m^2/ha (150-195 ft^2/a)
Site Index$_{100}$ = 34 m (110 ft).

- NEVADA BEACH: All-aged Jeffrey pine stand with a few scattered white fir. The campground was built in 1952, and is usually fully occupied from late spring until closed by snow. A few pines were infected by limb rust (Peridermium stalactiforme) and western gall rust (Endocronartium harknessii); several pines near the entrance road showed symptoms of injury from highway deicing salt.

Basal area = 25-145 m^2/ha (110-630 ft^2/a)
Site Index$_{100}$ = 21-27 m (70-90 ft).

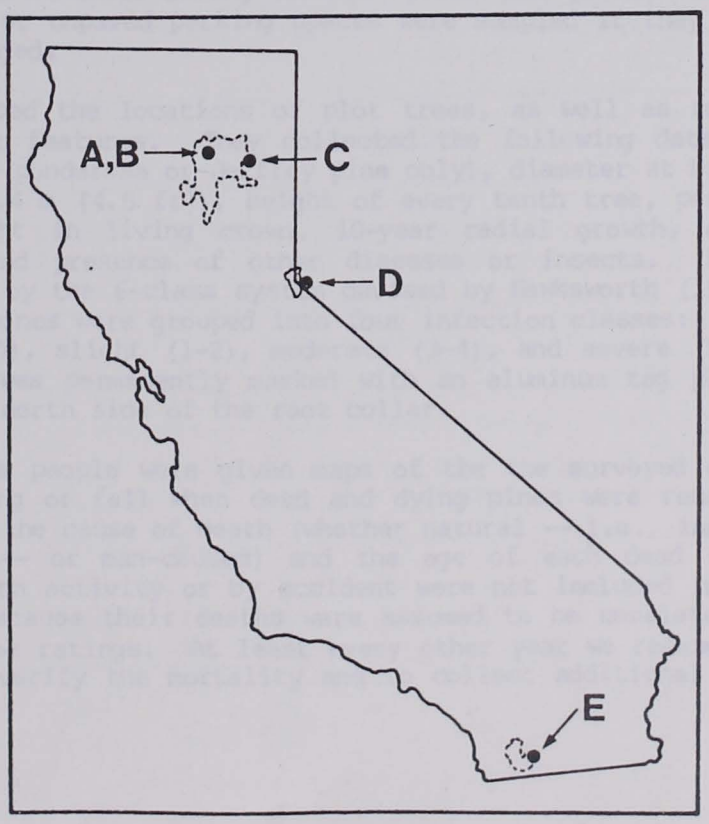

FIGURE 1. Locations of Campground Plots on National Forest (NF) Land in California and Nevada. (Bridge [A], Cave [B], and Merrill [C] on the Lassen NF; Nevada Beach [D] at Lake Tahoe; and Laguna [E] on the Cleveland NF; dotted lines indicate National Forest boundaries.)

- LAGUNA: Jeffrey pine predominant, with some Coulter pine at higher elevations on Laguna Mountain. The campground was built in the 1950's, and was rebuilt in 1962 and again in 1972. The camping season extends from May through November, and use is heavy throughout, especially on weekends. Heterobasidion annosum was prevalent throughout nearby stands. Some 75 pines adjacent to a meadow were slightly infected with Elytroderma disease.

  Basal area = 10-25 m^2/ha (45-110 ft^2/a)
  Site $Index_{100}$ = 18-24 m (60-80 ft).

DATA COLLECTION

Within selected campgrounds, the survey crew delineated a plot boundary around the entire camp or a major portion of it. Boundaries were placed to conform with roads and loops, so as to aid in readily relocating survey trees. The crew recorded all suitable ponderosa or Jeffrey pines 14 cm (6 in) d.b.h. and larger within the plot.

We excluded from the plots trees growing within 3 m (10 ft) of a road, ditch, toilet, building, or other construction that may have caused root damage. Accidentally-damaged or vandalized pines were rejected if they had broken tops, were scarred around one-half or more of their stems, had been skinned over one-half or more of their total heights, or had lost one-half or more of their living crowns. Trees near picnic tables, fireplaces, trails, or unpaved parking spaces were sampled if they were substantially undamaged.

The survey crew mapped the locations of plot trees, as well as roads, campsites, and other features. They collected the following data for each tree: species (ponderosa or Jeffrey pine only), diameter at breast height (d.b.h. at 1.4 m [4.5 ft]), height of every tenth tree, percent of total tree height in living crown, 10-year radial growth, dwarf mistletoe rating, and presence of other diseases or insects. Dwarf mistletoe was rated by the 6-class system devised by Hawksworth (1977). For data analysis, pines were grouped into four infection classes: none (Hawksworth rating 0), slight (1-2), moderate (3-4), and severe (5-6). Each surveyed tree was permanently marked with an aluminum tag placed below ground on the north side of the root collar.

Local Forest Service people were given maps of the the surveyed campgrounds. Each spring or fall when dead and dying pines were removed, they reported to us the cause of death (whether natural — i.e., insect- or disease-related — or man-caused) and the age of each dead tree. Trees killed by human activity or by accident were not included in the mortality records because their deaths were assumed to be unrelated to their dwarf mistletoe ratings. At least every other year we reexamined the campgrounds to verify the mortality and to collect additional data on cause of death.

RESULTS AND DISCUSSION

We analyzed the tree vigor, dwarf mistletoe intensity, and mortality data after seven years on the Lassen and Nevada Beach plots and after eight years on the Laguna plot. Because of their size and proximity, the three Lassen campgrounds were treated as a single plot.

TREE DIAMETER CLASSES AND INFECTION INTENSITY

Tables 1-3 show the diameters of the pines and their dwarf mistletoe ratings at the start of the survey. In all campgrounds, pole-size (14-26 cm [6-10 in] d.b.h.) and small sawtimber-size (27-52 cm [11-20 in] d.b.h.) pines predominated, comprising 80-90% of the trees surveyed in each plot; large sawtimber (53+ cm [21+ in] d.b.h.) made up the remainder of the stands. As in many long-established campgrounds, seedlings and saplings (up to 13 cm [6 in] d.b.h.) were rare or sparse in all of the plots. On the Lassen and Tahoe plots, poles and small sawtimber were about equal in number; at Laguna the number of small sawtimber was about twice that of poles, indicating that the stand had already lost many of the younger pines that were either suppressed or severely infected.

The percent of trees infected ranged from a high of 72% at Laguna, to 48% at Nevada Beach, to a low of 37% at the Lassen sites. Likewise, the

TABLE 1. Number and Percent of Ponderosa and Jeffrey Pines by Diameter Classes and Dwarf Mistletoe Ratings at Merrill, Bridge, and Cave Campgrounds in 1974.

DIAMETER (d.b.h.)	DWARF MISTLETOE RATINGS (Hawksworth 1977)				TOTAL
	NONE (0)	SLIGHT (1-2)	MODERATE (3-4)	SEVERE (5-6)	
14-26 cm (6-10 in)	131 (61%)	57 (27%)	15 (7%)	10 (5%)	213 (40%)
27-52 cm (11-20 in)	136 (63%)	66 (31%)	6 (3%)	7 (3%)	215 (41%)
53+ cm (21+ in)	67 (68%)	23 (24%)	3 (3%)	5 (5%)	98 (19%)
TOTAL	334 (63%)	146 (28%)	24 (5%)	22 (4%)	526

TABLE 2. Number and Percent of Jeffrey Pines by Diameter Classes and Dwarf Mistletoe Ratings at Nevada Beach Campground in 1974.

DIAMETER (d.b.h.)	DWARF MISTLETOE RATINGS (Hawksworth 1977)				TOTAL
	NONE (0)	SLIGHT (1-2)	MODERATE (3-4)	SEVERE (5-6)	
14-26 cm (6-10 in)	364 (50%)	178 (24%)	95 (13%)	96 (13%)	733 (48%)
27-52 cm (11-20 in)	371 (58%)	152 (24%)	73 (12%)	41 (6%)	637 (41%)
53+ cm (21+ in)	74 (42%)	43 (25%)	40 (23%)	18 (10%)	175 (11%)
TOTAL	809 (52%)	373 (24%)	208 (14%)	155 (10%)	1545

TABLE 3. Number and Percent of Jeffrey Pines by Diameter Classes and Dwarf Mistletoe Ratings at Laguna Campground in 1973.

DIAMETER (d.b.h.)	DWARF MISTLETOE RATINGS (Hawksworth 1977)				TOTAL
	NONE (0)	SLIGHT (1-2)	MODERATE (3-4)	SEVERE (5-6)	
14-26 cm (6-10 in)	86 (33%)	48 (18%)	57 (22%)	71 (27%)	262 (27%)
27-52 cm (11-20 in)	151 (28%)	94 (18%)	152 (28%)	138 (26%)	535 (55%)
53+ cm (21+ in)	39 (22%)	42 (24%)	49 (28%)	47 (26%)	177 (18%)
TOTAL	276 (28%)	184 (19%)	258 (27%)	256 (26%)	974

percent of trees in the severely-infected category (dwarf mistletoe ratings 5-6) ranged from 26% at Laguna, to 10% at Nevada Beach, to 4% on the Lassen. Within each plot, there was little difference in the percent of infection for each diameter class by infection category (Tables 1-3).

Figure 2 depicts the relative differences in dwarf mistletoe intensity at the start of the survey. The plots may be seen to represent three stages in the gradual spread and intensification of the parasite. The infestation was most severe at Laguna Campground, where the number of trees in each of the four rating classes was about equal. The profile of infection at Laguna illustrates a longer and perhaps more aggressive history of spread and intensification than at either the Lake Tahoe or Lassen plots. Laguna may well be the worst case of untreated dwarf mistletoe in California campgrounds.

RADIAL GROWTH, PERCENT LIVE CROWN, AND DWARF MISTLETOE

Figures 3-5 illustrate the relationships between radial growth, live crown, and dwarf mistletoe infection for all pines at the start of the survey. The upper left of each figure represents the mean 10-year radial growth for the most vigorous pines (those with full crowns and no dwarf mistletoe); the lower right represents the growth of the least-healthy pines (those with poor crowns and severe mistletoe). Most of the remaining points on the graphs are intermediate to these extremes, creating an upper surface that slopes forward and to the right as infection increases and tree crowns decline.

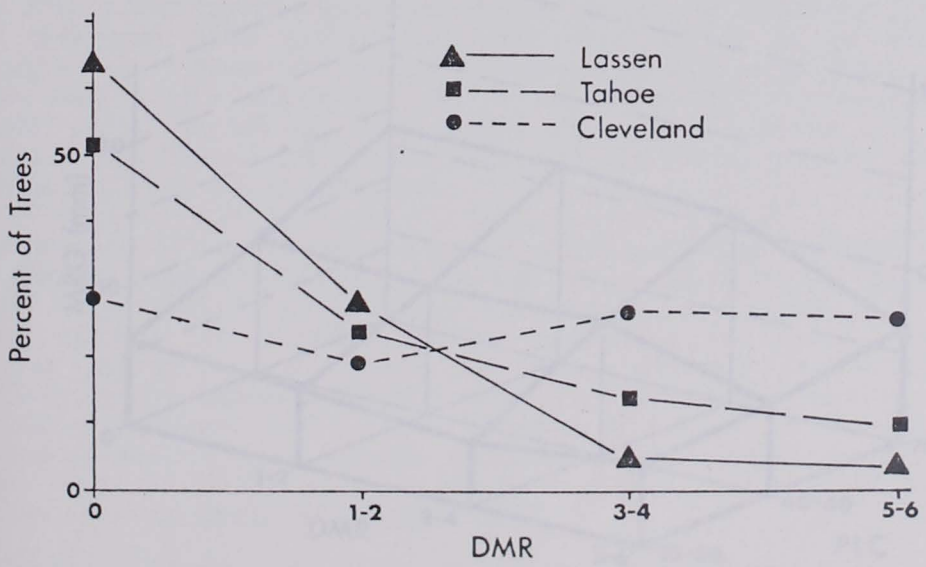

FIGURE 2. Relative Severity of Dwarf Mistletoe Infection at Campground Plots on the Lassen National Forest, Lake Tahoe Basin, and Cleveland National Forest in 1973-74. (DMR = dwarf mistletoe rating.)

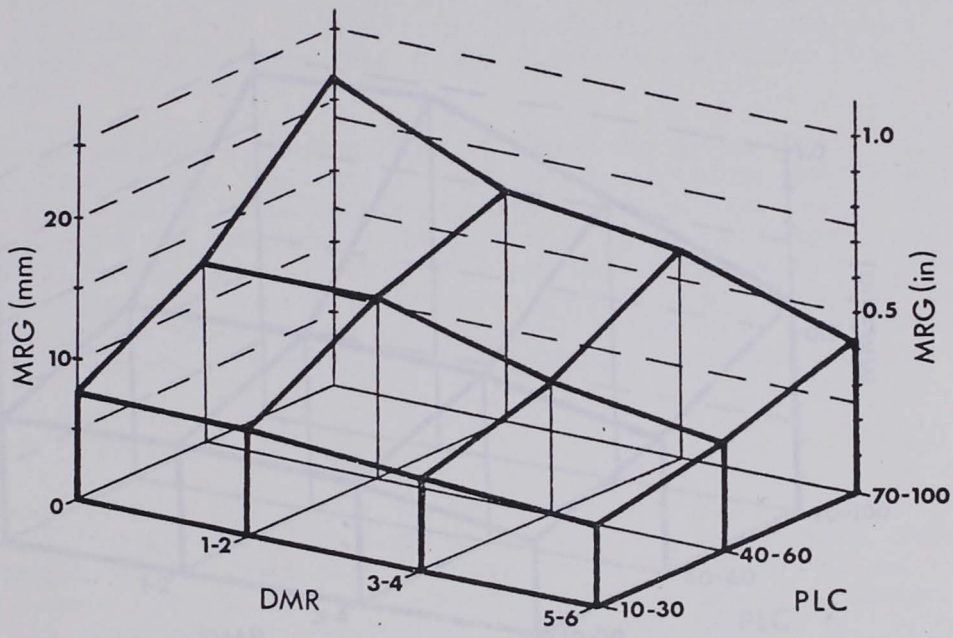

FIGURE 3. Mean 10-Year Radial Growth (MRG) of Ponderosa and Jeffrey Pines by Percent Live Crown (PLC) and Dwarf Mistletoe Ratings (DMR) at Merrill, Cave, and Bridge Campgrounds, Lassen National Forest, in 1974.

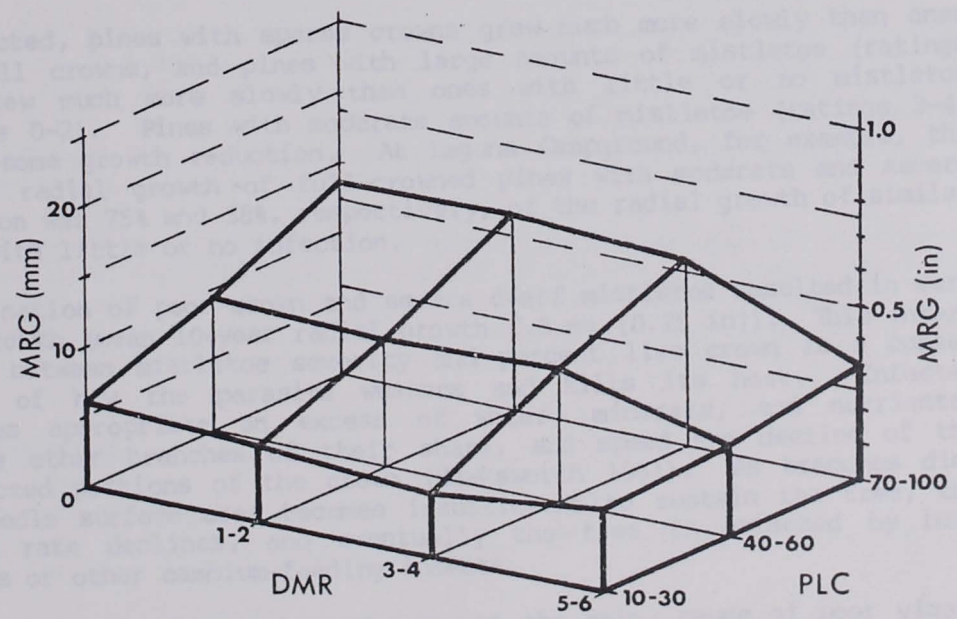

FIGURE 4. Mean 10-Year Radial Growth (MRG) of Jeffrey Pines by Percent Live Crown (PLC) and Dwarf Mistletoe Ratings (DMR) at Nevada Beach Campground, Lake Tahoe Basin, in 1974.

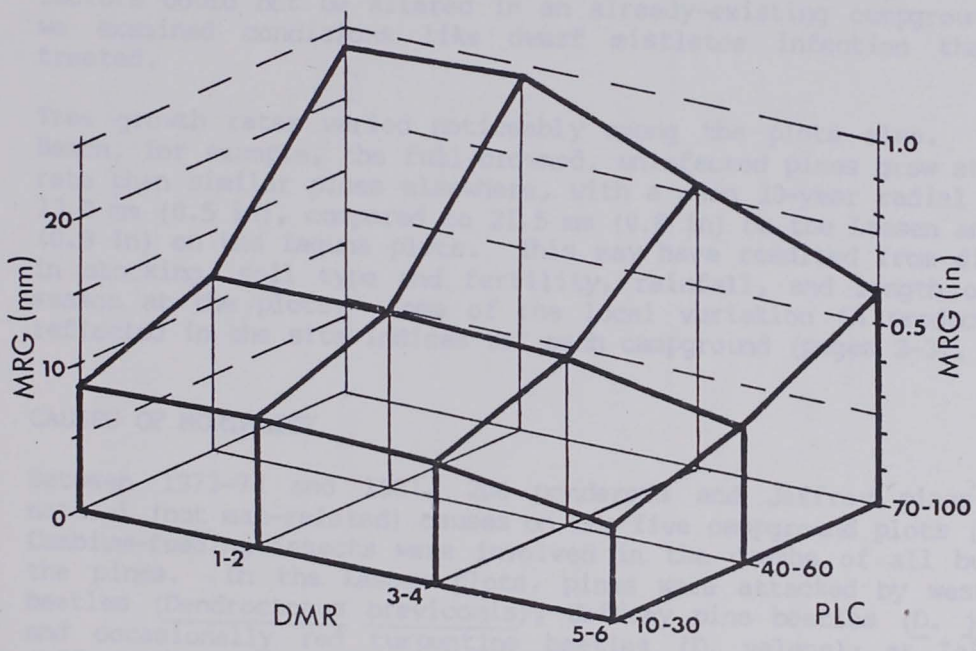

FIGURE 5. Mean 10-Year Radial Growth (MRG) of Jeffrey Pines by Percent Live Crown (PLC) and Dwarf Mistletoe Ratings (DMR) at Laguna Campground, Cleveland National Forest, in 1973.

As expected, pines with sparse crowns grew much more slowly than ones with full crowns, and pines with large amounts of mistletoe (ratings 5-6) grew much more slowly than ones with little or no mistletoe (ratings 0-2). Pines with moderate amounts of mistletoe (ratings 3-4) showed some growth reduction. At Laguna Campground, for example, the 10-year radial growth of full-crowned pines with moderate and severe infection was 75% and 58%, respectively, of the radial growth of similar pines with little or no infection.

A combination of poor crown and severe dwarf mistletoe resulted in very slow growth (mean 10-year radial growth 6.5 mm [0.25 in]). This interaction between mistletoe severity and percent live crown is a consequence of how the parasite weakens and kills its host. Infected branches appropriate an excess of water, minerals, and nutrients, deprive other branches of their share, and speed the decline of the uninfected portions of the crown (Hawksworth 1961). As branches die, the needle surface area becomes insufficient to sustain the tree, the growth rate declines, and eventually the tree is attacked by bark beetles or other cambium-feeding insects.

Dwarf mistletoe was a major, though not the sole, cause of poor vigor. Some pines in each plot were thin-crowned and slow-growing despite having little or no infection. These pines probably were affected by many of the site, stand, and genetic factors that influence tree growth, and these factors, when detrimental, may contribute to or mask the

effects of mistletoe infection. This is illustrated in Figures 3-5, where the growth rates of trees with intermediate-to-poor crowns (60% live crown or less) were little affected by increased mistletoe severity. At the start of the survey, we knew that many of these other factors could not be altered in an already-existing campground; hence, we examined conditions like dwarf mistletoe infection that can be treated.

Tree growth rates varied noticeably among the plots also. At Nevada Beach, for example, the full-crowned, uninfected pines grew at a slower rate than similar pines elsewhere, with a mean 10-year radial growth of 13.2 mm (0.5 in), compared to 21.5 mm (0.8 in) on the Lassen and 23.2 mm (0.9 in) on the Laguna plots. This may have resulted from differences in stocking, soil type and fertility, rainfall, and length of growing season at the plots. Some of the local variation in productivity is reflected in the site indices for each campground (pages 2-3).

CAUSES OF MORTALITY

Between 1973-74 and 1981, 206 ponderosa and Jeffrey pines died of natural (not man-related) causes on the five campground plots (Table 4). Cambium-feeding insects were involved in the deaths of all but one of the pines. On the Lassen plots, pines were attacked by western pine beetles (Dendroctonus brevicomis), Jeffrey pine beetles (D. jeffreyi), and occasionally red turpentine beetles (D. valens); at Lake Tahoe, Jeffrey pine beetles were the only bark beetles found. At Laguna Campground, California flatheaded borers (Melanophila californica) were associated with most of the dead trees, although pine engravers (Ips spp.) contributed to borer attack by killing some tops. One pine died when its stem broke at a large dwarf mistletoe swelling.

Several plot trees died from man-related activity, and were excluded from these results. For example, at Bridge Campground on the Lassen eight trees died within three years after being injured by a 102 cm (40 in) d.b.h. sugar pine that was felled in 1976. At Nevada Beach, two pines near the entrance road died after exhibiting severe salt injury symptoms for several years.

Of the 206 trees that died of natural causes on all plots, three-quarters (160) were infected with dwarf mistletoe, and almost one-half (97) were severely infected at the start of the survey (Table 4). These 97 dead pines represent 22% of all pines originally rated severely-infected; by contrast, only 3% of the mistletoe-free trees had died by 1981.

PATTERNS OF MORTALITY BY PLOT

Cumulative percent mortality for each year of the survey is shown in Figures 6-8. Each campground plot is considered separately in the results that follow.

LASSEN PLOTS (MERRILL, CAVE, AND BRIDGE). Mortality was almost wholly confined to the drought and post-drought years 1977-78 (Figure 6), when

TABLE 4. Total Mortality of Ponderosa and Jeffrey Pines by Dwarf Mistletoe Ratings at Campground Plots on the Lassen National Forest, Lake Tahoe Basin Management Unit, and Cleveland National Forest, from 1973 to 1981.

	DWARF MISTLETOE RATING (Hawksworth 1977)									
	NONE (0)		SLIGHT (1-2)		MODERATE (3-4)		SEVERE (5-6)		ALL TREES IN PLOT	
PLOT NAME	DEAD/ALIVE	%DEAD	DEAD/ALIVE	%DEAD	DEAD/ALIVE	%DEAD	DEAD/ALIVE	%DEAD	DEAD/ALIVE	%DEAD
LASSEN (1974-81)	35/299	10.5	15/131	10.3	8/16	33.3	8/14	36.4	66/460	12.6
LAKE TAHOE (1974-81)	7/802	0.9	3/370	0.8	8/200	3.8	37/118	23.9	55/1490	3.6
LAGUNA (1973-81)	4/272	1.4	11/173	6.0	18/240	7.0	52/204	20.3	85/889	8.7
TOTAL	46/1373	3.2	29/674	4.1	34/456	6.9	97/336	22.4	206/2839	6.8

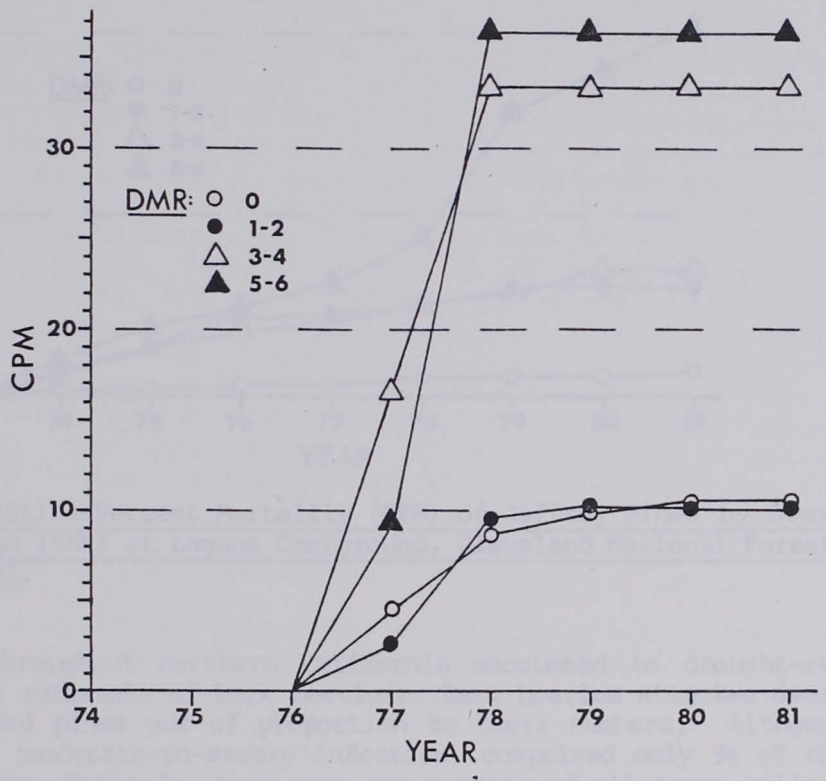

FIGURE 6. Cumulative Percent Mortality (CPM) of Ponderosa and Jeffrey Pines by Dwarf Mistletoe Ratings (DMR) at Merrill, Cave and Bridge Campgrounds, Lassen National Forest, from 1974 to 1981.

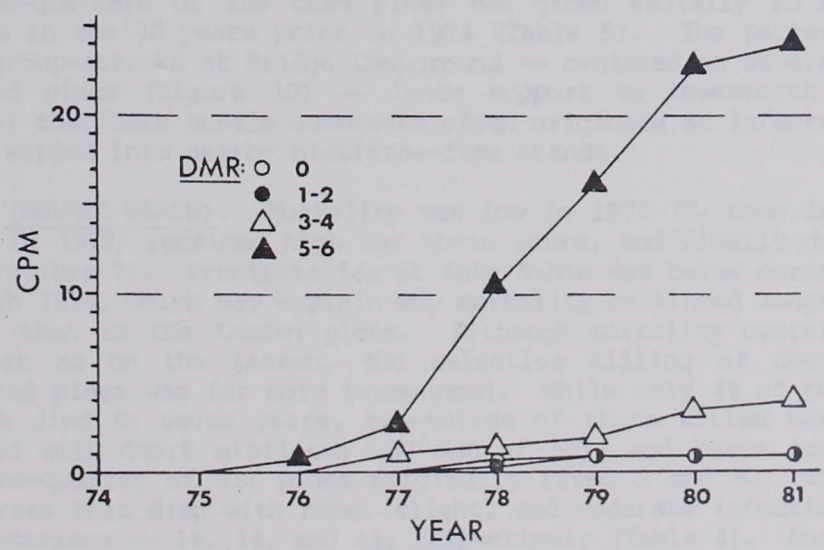

FIGURE 7. Cumulative Percent Mortality (CPM) of Jeffrey Pines by Dwarf Mistletoe Ratings (DMR) at Nevada Beach Campground, Lake Tahoe Basin Management Unit, from 1974 to 1981.

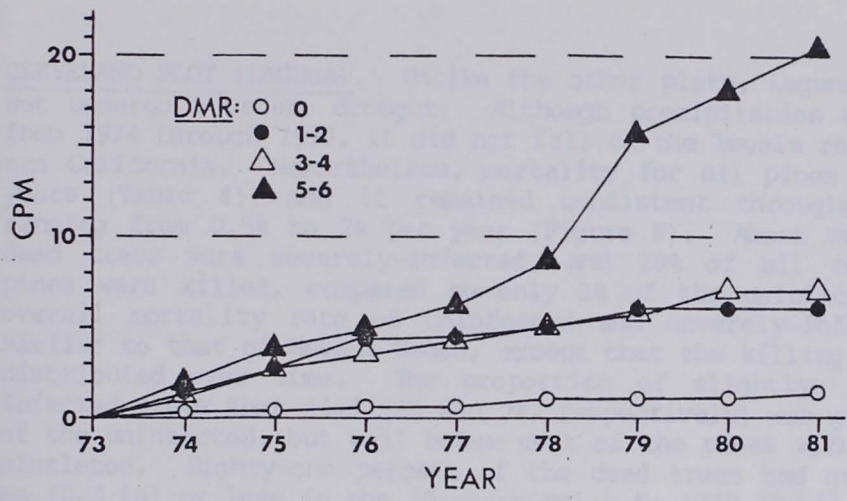

FIGURE 8. Cumulative Percent Mortality (CPM) of Jeffrey Pines by Dwarf Mistletoe Ratings (DMR) at Laguna Campground, Cleveland National Forest, from 1973 to 1981.

many conifers throughout northern California succumbed to drought-related stress and outbreaks of bark beetles. Bark beetles attacked dwarf mistletoe-infected pines out of proportion to their numbers. Although pines rated 3-6 (moderate-to-severe infection) comprised only 9% of the pines in the plots (Table 1), they were one-quarter of all trees killed. And, while mortality in the plots was 13% overall and 10% of the uninfected trees died, more than one-third of the moderately- and severely-infected pines were killed in the same period. Furthermore, bark beetles attacked trees already weakened by dwarf mistletoe or other stresses: three-quarters of the dead pines had grown radially 10 mm (0.4 in) or less in the 10 years prior to 1974 (Table 5). The pattern of bark beetle group-attacks at Bridge Campground -- centered on several severely-infected pines (Figure 10) — lends support to Hawksworth's contention (1961) that bark beetle outbreaks often originate at infected pines and later expand into nearby mistletoe-free stands.

LAKE TAHOE PLOT (NEVADA BEACH). Mortality was low in 1975-77, then increased greatly in 1978, remained high for three years, and finally declined in 1981 (Figure 7). Precipitation at Lake Tahoe was below normal from 1976 through 1979, which may explain why mortality continued longer at Nevada Beach than in the Lassen plots. Although mortality overall was not as great as on the Lassen, the selective killing of dwarf mistletoe-stressed pines was far more pronounced. While only 4% of the campground pines died in seven years, two-thirds of those killed were severely-infected with dwarf mistletoe (37 out of 55), and these comprised almost one-quarter of all pines originally rated 5 and 6. The proportion of trees that died with none, slight, and moderate infection was small by comparison -- 1%, 1%, and 4%, respectively (Table 4). And, the mortality rate of severely-infected pines was high during and after the drought, with 7-8% of the remaining trees rated 5-6 being killed each year. Ninety-one percent of all trees that died had been growing poorly in the 10 years prior to 1974 (Table 5).

CLEVELAND PLOT (LAGUNA). Unlike the other plots, Laguna Campground did not undergo a severe drought. Although precipitation was below normal from 1974 through 1977, it did not fall to the levels recorded in northern California. Nevertheless, mortality for all pines was 9% in eight years (Table 4), and it remained consistent throughout the survey, ranging from 0.5% to 2% per year (Figure 8). About two-thirds of all dead trees were severely-infected, and 20% of all severely-infected pines were killed, compared to only 1% of the uninfected trees. The overall mortality rate of uninfected and severely-infected pines was similar to that of Nevada Beach, except that the killing was more evenly distributed over time. The proportion of slightly- and moderately-infected trees that died (6% and 7%, respectively) was greater than that of the uninfected, but well below that of the pines with the most dwarf mistletoe. Eighty-one percent of the dead trees had grown radially 10 mm (0.4 in) or less in the 10 years prior to 1973 (Table 5).

AGE AT DEATH OF CAMPGROUND PINES

The dead pines in the campgrounds were generally young trees that should have been at the peak of their vigor (Table 6). Ninety-one percent were 100 years of age or younger at death, and more than two-fifths were between 61 and 80 years of age. The campground sites may not support pines to their fullest maturity, but uninfected trees 200 years of age and older were found in all of the plots. However, because we did not collect systematic data on the ages of live trees, we cannot say with certainty whether the trees that died were significantly younger than the living pines.

ROOT DISEASE AND MORTALITY

Annosus root disease was not found in any of the dead pines. A 1977 aerial photographic survey of Laguna Mountain identified three potential disease centers in the campground (Wood et al. 1979), but we were unable to confirm the presence of the disease. Nevertheless, the clustered pattern of dead trees in two of the sites (Figure 9), the long history of dead and dying pines, and the prevalence of the disease in the vicinity make it inadvisable to rule out the involvement of H. annosum in past or future mortality.

TABLE 5. Number and Percent of Dead Pines by 10-Year Radial Growth at Campground Plots on the Lassen National Forest, Lake Tahoe Basin, and Cleveland National Forest, 1973-1981.

PLOT NAME	TEN-YEAR RADIAL GROWTH			TOTAL
	0-10 mm (0-0.4 in)	11-20 mm (0.5-0.8 in)	21+ mm (0.9+ in)	
Lassen (1974-81)	49 (74%)	15 (23%)	2 (3%)	66
Tahoe (1974-81)	50 (91%)	4 (7%)	1 (2%)	55
Laguna (1973-81)	69 (81%)	15 (18%)	1 (1%)	85
TOTAL	168 (82%)	34 (16%)	4 (2%)	206

TABLE 6. Number and Percent of Dead Pines by Age at Death at Campground Plots on the Lassen National Forest, Lake Tahoe Basin, and Cleveland National Forest, 1973-1981.

PLOT NAME	AGE AT DEATH (in YEARS)					TOTAL
	<40	41-60	61-80	81-100	101+	
Lassen (1974-81)	0	10 (15%)	29 (44%)	22 (33%)	5 (8%)	66
Tahoe (1974-81)	2 (4%)	14 (26%)	27 (49%)	3 (5%)	9 (16%)	55
Laguna (1973-81)	1 (1%)	19 (22%)	34 (40%)	26 (31%)	5 (6%)	85
TOTAL	3 (1%)	43 (21%)	90 (44%)	51 (25%)	19 (9%)	206

CONCLUSIONS

The longevity of campground pines is one of the recreation manager's main concerns. Where a substantial number of pines are severely infected with dwarf mistletoe, in poor health, and consequently dying at a rate of 2-5% annually, campgrounds are gradually denuded and become less desirable to visitors. Natural regeneration is often absent in campgrounds, and planting is expensive and often unsuccessful; as a result, full-grown trees are literally irreplaceable within human lifetimes. Prolonging the lives of individual trees and ensuring the longevity of young pines becomes a necessity if a campground is to be maintained.

The dilemma may be illustrated by an aerial view of Laguna Campground (Figure 9), where in some campsites one-half to all of the pines were lost in eight years. In the loop at the upper right, what was once a shady stand of trees has become a meadow -- open, hot, and dry during the summer when visitor use is greatest. Although young black oaks (Quercus kelloggii) are growing at the bases of many threatened pines and will eventually replace them, many years will pass before they attain a shade-giving shape and size.

At Laguna Campground, the loss of pines was gradual over many years, although it was approaching a critical stage by the end of the survey. By contrast, at Bridge Campground on the Lassen a catastropic loss occurred as a result of the 1976-77 drought, entirely removing the canopy from parts of the plot in two years (Figure 10). No trees or shrubs grew to replace the pines in three years; without expensive and well-tended plantings, nothing will replace them for many years.

The mortality rates at the Lake Tahoe and Laguna plots agree well with other published results. For example, Lightle and Hawksworth (1973) reported on the fate after 20 years of untreated ponderosa pines infected by southwestern dwarf mistletoe (Arceuthobium vaginatum subsp. cryptopodum) at Grand Canyon National Park. Fifty-two percent of the severely-infected pines died between 1950 and 1970, while only 4% of the uninfected pines died during the same period. If the current mortality rates continue on the Tahoe and Laguna plots, we may expect about 50% of the pines rated 5-6 to be dead after 20 years.

Left untreated, dwarf mistletoe will continue to intensify in the already-infected trees. Although we did not re-rate the pines in our plots, we suspect that the intensification rate reported in Arizona, where trees rated 1-4 increased to the next higher rating in nine years (Lightle and Hawksworth 1973), may apply to the Tahoe and Laguna plots as well. If this is so, most of the pines rated moderate or severe in 1973/74 -- one-quarter of the pines at Nevada Beach and one-half of those at Laguna Campground -- may be either severely infected or dead in 10-15 years.

The situation at the Lassen plots is somewhat different, since the losses there were sudden rather than chronic, mistletoe infection was less intense, and one-third of the moderately- and severely-infected pines are now dead. If moisture remains adequate, further losses of pines may be slight. However, if a drought or other major stress

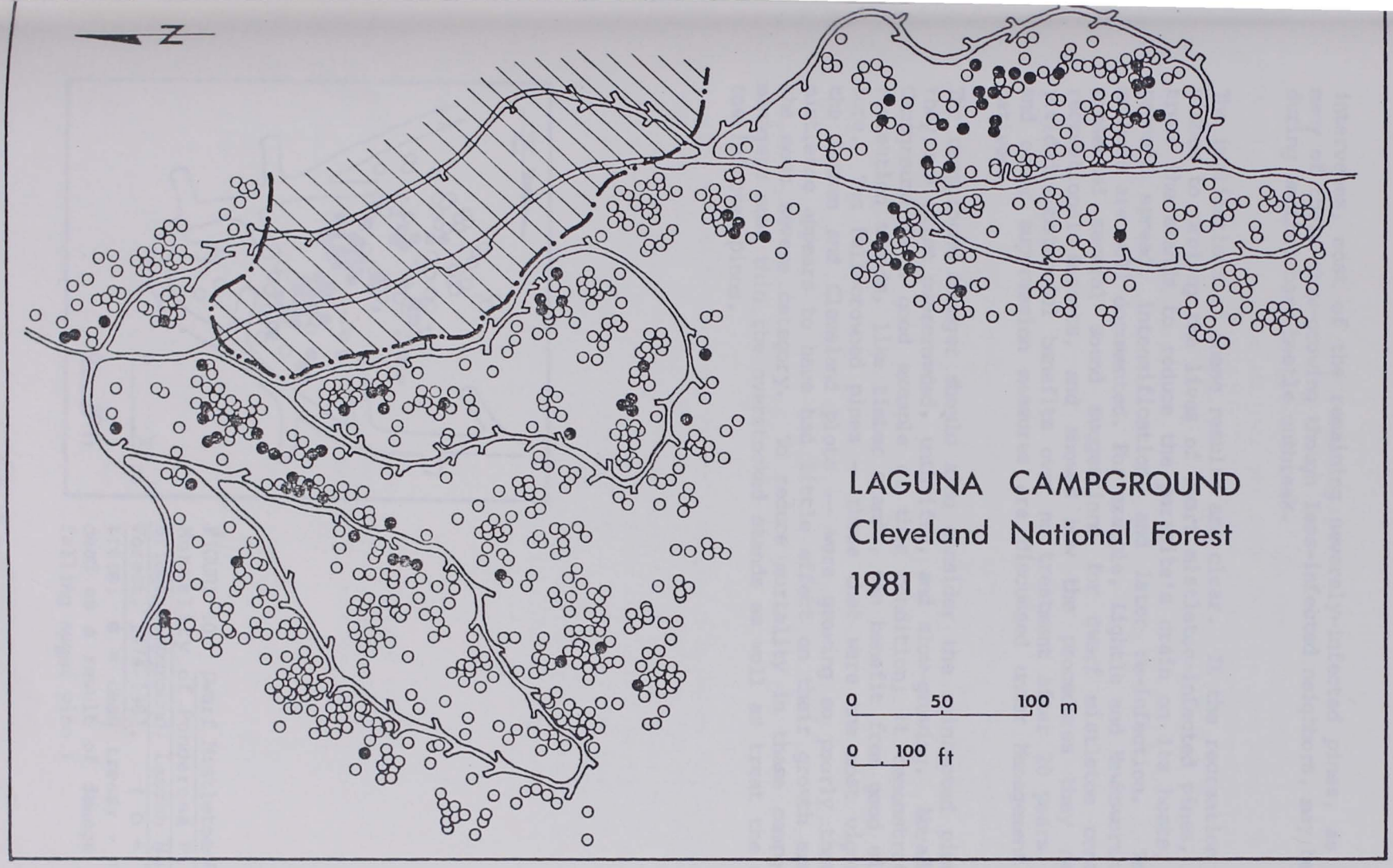

FIGURE 9. Dwarf Mistletoe-Related Mortality of Jeffrey Pines at Laguna Campground, Cleveland National Forest, 1973-1981. (o = living trees; ● = dead trees. Shaded area denotes mixed Coulter and Jeffrey pine.)

intervenes, most of the remaining severely-infected pines, as well as many of their slow-growing though less-infected neighbors, may be killed during another bark beetle outbreak.

The implications of these results are clear. If the recreation manager wishes to prolong the lives of dwarf mistletoe-infected pines, he must treat the stands to reduce the parasite's drain on its hosts, and to prevent spread, intensification, and later re-infection. Treatment methods are well documented. For example, Lightle and Hawksworth (1973) presented several sound suggestions for dwarf mistletoe control in recreational forests, and showed how the procedures they recommend yielded substantial benefits over no treatment after 20 years. These and other suppression measures are discussed under Management Alternatives.

The campground manager should also consider the uninfected pines, for they are often overcrowded, unthrifty, and slow-growing. Nevada Beach Campground is a good example of this condition; it demonstrates how recreation stands, like timber stands, can benefit from good silviculture. The full-crowned pines -- those that were the most vigorous on the Lassen and Cleveland plots -- were growing so poorly that dwarf mistletoe appears to have had little effect on their growth except in the most severe category. To reduce mortality in these campgrounds, managers must thin the overstocked stands as well as treat the mistletoe-infected pines.

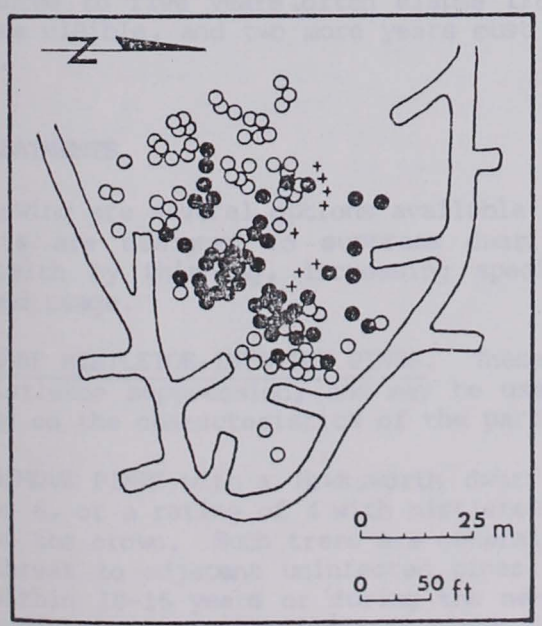

FIGURE 10. Dwarf Mistletoe-Related Mortality of Ponderosa Pines at Bridge Campground, Lassen National Forest, 1974-1981. (O = living trees; ● = dead trees; + = trees dead as a result of damage from a falling sugar pine.)

MANAGEMENT ALTERNATIVES

Historically, management of these campgrounds has been custodial: dead and hazardous trees have been removed and some conifers and hardwoods planted to fill gaps in the stands, but little active manipulation has been attempted. If the campgrounds are to provide a continuing yield of recreational benefits for generations to come, managers must take a more aggressive approach. Dwarf mistletoe treatment, stand thinning, and the care and planting of replacement conifers and hardwoods are an important first step.

DWARF MISTLETOE BIOLOGY

In order to choose wisely among alternative treatments, the manager should know the fundamentals of dwarf mistletoe biology. The dwarf mistletoes are parasitic, flowering plants that grow only on living conifers; they obtain most of their nutrients and all of their minerals and water from their hosts. In advanced stages they often cause the host to form witches' brooms, which are dense masses of contorted branches that divert nutrients and water from the rest of the crown. The principal hosts of western dwarf mistletoe (Arceuthobium campylopodum) are ponderosa and Jeffrey pines; Coulter (Pinus coulteri) and knobcone pines (P. attenuata) are also attacked, especially where they grow in association with the principal hosts.

Dwarf mistletoes spread between and within tree crowns by seeds forcibly ejected from the female plants. Horizontal spread is limited to the distance the seeds travel, usually 20-60 feet; in a strong wind, seed may be carried as far as 100 feet. Because of various limits to spread, the actual spread rate through an even-aged stand is one to two feet per year. Upward spread within a crown is usually four to six inches per year. Three to five years often elapse from infection until mistletoe shoots are visible, and two more years must pass before viable seed are produced.

STAND TREATMENTS

The following are several options available to campground managers. The treatments are designed to suppress dwarf mistletoe, and to promote stand health by thinning, increasing species diversity, and rotating campground usage.

TREAT DWARF MISTLETOE-INFECTED PINES. These are general guidelines for dwarf mistletoe suppression, and may be used singly or in combination, depending on the characteristics of the particular campground stand.

- REMOVE PINES with a Hawksworth dwarf mistletoe rating of 5 or 6, or a rating of 4 with mistletoe in the upper one-third of the crown. Such trees are generally not prunable, pose a threat to adjacent uninfected pines, and will probably die within 10-15 years or during the next drought. It is also advisable to remove infected pines that will have less than

30% live crown after pruning, or are growing in dense aggregations where removal of selected individuals would benefit neighboring uninfected or slightly-infected pines.

- PRUNE LOWER BRANCHES of pines with a rating of 3 or less, or a rating of 4 and no mistletoe in the upper one-third of the crown. Remove all lower branches at the bole, up to and including the second whorl above the highest visible mistletoe plant; whenever possible, avoid removing more than one-half of a tree's live crown. Reenter pruned stands within two to three years to remove previously-undetected infections, as dwarf mistletoe cannot be eliminated without at least two treatments.

- REMOVE WITCHES' BROOMS from large, high-value trees, as they will likely increase in vigor when the physiological drain of the brooms is removed; it may not be possible or acceptable to prune smaller branch infections. Use this option only if an infected overstory must be retained, and no susceptible trees are within range of the remaining mistletoe plants. This treatment will not eliminate dwarf mistletoe, nor will it prevent future spread.

- CREATE HOST-FREE BUFFER ZONES around treated stands to prevent mistletoe from reentering or -- when the parasite is not eliminated, as in broom pruning -- from leaving the site. Buffer strips should be at least as wide as the height of the highest mistletoe plants in the adjacent infected stand. Meadows, roads, rivers and creeks, clearings, and aggregations or plantings of non-host trees are excellent barriers to spread.

THIN OVERSTOCKED STANDS. Despite dwarf mistletoe treatment, the benefits from reducing or eliminating infection may be offset by continuing competition for growing space in overcrowded stands. Even where mistletoe is absent, overstocking may contribute to poor tree vigor and an unnecessarily high risk of death from bark beetle attack. Although privacy and esthetic requirements in campgrounds may prevent thinning to stocking levels optimum for timber-producing forests, some thinning will be necessary if campground stands are to increase in vigor and resistance to pest attack.

FAVOR AND PLANT NON-HOST CONIFERS AND HARDWOODS. Because western dwarf mistletoe (A. campylopodum) infects neither the hardwoods nor most of the conifers growing with the ponderosa and Jeffrey pines in the surveyed campgrounds, managers may favor these non-hosts so that they become a larger component of the campground stands. Selected individuals or small aggregations of these non-host species may be retained as buffers to infection, or as eventual replacements for severely-infected pines that cannot be removed during mistletoe treatment. Wherever there are pure stands of severely-infected pines, planting may be the only way to ensure that new trees replace the pines that die or are removed. However, for plantings to survive in campgrounds, managers

must be prepared to protect them with stakes, fencing, drip irrigation, a visitor information program, and other expensive treatments.

ROTATE CAMPGROUND USAGE. Successful mistletoe treatment and thinning are sometimes incompatible with campground management, and partial treatments are usually not biologically or economically sound. In such cases it may be advisable to close a campground so that treatment can be carried out properly and stands revegetated where necessary. Although closing part or all of a campground for 10-15 years may seem impossible in the short run, the advantages that accrue from healthier stands and a greater mix of tree species and ages may offset the temporary loss of the site. Severely-infected campground stands will continue to decline until they finally must be closed; it may be cheaper to revitalize the stands while they are still salvageable, rather than wait until the old stand must be destroyed and completely regenerated. And, when campgrounds must be closed because of a shortage of money and personnel, managers could select for closure those sites where mistletoe treatment and stand rejuvenation are most needed.

INTEGRATED PEST MANAGEMENT

We have emphasized the role of dwarf mistletoe -- and to a lesser extent, of overstocking, drought, and bark beetles -- in reducing stand vigor and increasing the risk of tree death. However, these pests are often only part of a larger set of stand, site, and pest factors. Before treatment, each campground should be evaluated thoroughly to ensure that all pests are considered in the management alternative selected. For example, proper slash disposal to prevent build-up of pine engraver beetles (Ips spp.), and stump treatment to prevent initiation or spread of root diseases often must accompany dwarf mistletoe treatment and thinning. Too often managers have dealt only with single pests, thereby neglecting other causes of growth loss and mortality to the detriment of the stand and of management objectives.

ASSISTANCE TO FOREST MANAGERS

Forest Pest Management (FPM) provides technical assistance, consultation, and training to National Forests, National Parks, and other Federal lands, as requested. On State and private lands, assistance is available from insect and disease management people in the California Department of Forestry. A major role of such specialists is to provide forest land managers with the biological information they need to make sound decisions.

For National Forests, FPM will provide funds, if available, for pest management projects based on environmental acceptability, biological effectiveness, and economic efficiency (see FSM 3453.2-3453.4). If a campground manager wishes to request funds for dwarf mistletoe suppression, he must prepare a project proposal (Form FS-3400-2) and an environmental assessment. These documents must include a concise description of project objectives, a copy of the biological evaluation, a project work plan, a project safety plan, and a benefit-cost analysis.

Upon request, FPM will assist Forests in selecting suppression treatments, and in preparing the necessary documents for approval by the Forest Supervisor or Regional Forester.

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